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**The Comparative Effect of Muriate and Sulfate of
Potash on the Composition and Quality of
White Burley Tobacco.**

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(RESEARCH BULLETIN)



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**The Comparative Effect of Muriate and Sulfate of
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White Burley Tobacco.**

By P. E. KARRAKER

Considerable experimental work has been done comparing the effects of muriate and sulfate of potash on the composition and quality of tobacco. Garner, McMurtry, Bowling and Moss have reported recently on work along this line and have given numerous citations to other similar publications.*

Until comparatively recently White Burley tobacco has been grown in Kentucky with practically no use of commercial fertilizers. The crop was grown almost entirely on the highly productive Central Kentucky Bluegrass soils and to a very large extent on land that had been for a number of years in bluegrass-white clover sod. Such soil conditions apparently furnished an excellent nutrient supply for large yields of high-quality tobacco. Within the last ten or fifteen years, however, the crop has been grown to a greater extent on land in short rotations, where nutrient conditions were less favorable, and its production has spread to sections outside the Bluegrass, with naturally less productive soils. Increasing use of fertilizers resulted and the question arose as to the importance of using fertilizers low in chlorine and in particular of using sulfate rather than muriate of potash.

The Experiments. Work was begun in this connection at the Experiment Station in 1924. At that time the usual fertilizer recommendations in other parts of the country were to use fertilizers for tobacco containing very little or no chlorine. However, in view of the small to moderate fertilizer applications used for White Burley tobacco it did not seem that the kind of

* Jour. Agric. Res., Vol. 40, pp. 627-647, 1930.

the potassium carrier and the percentage of chlorine present would be a matter of any consequence. It was mainly to determine the correctness of this view that the work at the Station was begun. Experimental work done since at various places has shown that there is not only no detrimental but possibly a slight beneficial effect from a small amount of chlorine in fertilizers for at least some types of tobacco.

The work at the Experiment Station was continued thru the year 1929.* In the main the field work consisted in the growth of White Burley tobacco on small plats which received treatments of varying amounts of muriate and sulfate of potash, separately. The tobacco was examined carefully for effects of the treatments on quality. In the laboratory certain determinations were made as to the effects of the treatments on its composition. Smoking tests were made on the tobacco in two years of the experiment.

The tobacco was grown on the Lexington Experiment Station farm. A different area was used each year to conform to the usual plan of growing White Burley tobacco in long-time rotation and to avoid cumulative effects of fertilizer additions. The plats ranged in size in different years from 1/120 to 1/30 of an acre. The potash treatments, except a few to be referred to later, are shown in detail in Table 1. Only those treatments were used in any year for which chlorine percentages appear in the table. It will be noted that there was a considerable range in rate of application of the materials in many years of the experiment. The applications were made along the row at time of setting the tobacco. The usual commercial fertilizer materials were used.

In 1927 and 1928 tobacco also was grown on approximately acre areas, and fertilized respectively with muriate and sulfate of potash. This tobacco was sold to Liggett and Myers with the understanding that the effects of the treatments on quality of the tobacco be determined in their research department after the tobacco had gone thru the regular redrying, factory treatment and aging process of the Company.

* The field work was directed mainly by Prof. E. J. Kinney.

The Soil. The soils of the areas where the tobacco was grown are silt loams to a depth of ten to fifteen inches grading into well-granulated clay loams underneath. They are of limestone origin. The areas used were not equally productive but on the whole were slightly above the Central Bluegrass Region in this respect. The soils of this region are well known for their high productivity and especially large native supply of phosphorus. Uniform applications of sodium nitrate and superphosphate were made on all plats in 1924, 1925 and 1929 but were omitted in other years. Except for the special fertilizer treatments, the tobacco was grown and handled in practically the usual farm way.

Methods of Analysis. For the laboratory determinations* one sample of tobacco was prepared from each plat. Leaves were selected to represent the entire tobacco produced on a plat, except in 1926 when only the "leaf" and "lugs" grades (leaves located approximately midway on the stalks) were sampled. The samples were prepared for analysis by rubbing them in air-dry condition thru a sieve with eight meshes per inch. All the midrib and larger pieces of vein material were removed in this process. The portions used for chlorine analysis were moistened with sodium carbonate solution and ashed in an electric muffle at a temperature not above 600°C. Chlorine was determined by the A. O. A. C. official volumetric method. The portions used for sulfur analysis were ashed by the A. O. A. C. tentative magnesium nitrate method and sulfur was determined in the usual way.

Chlorine Content. The percentages of chlorine in the samples of tobacco grown on the different plats are given in Table 1. The effect of the muriate treatments, as expected, was to increase greatly the amount of chlorine in the leaf. In a general way, considering the last four years of the experiment, the percentage of chlorine in the leaf was increased in proportion to the amount applied in the muriate treatments up to 400 pounds per acre, inclusive. There was a further increase in

* The chlorine and sulfur analyses for the 1928 and 1929 tobacco, were made by Mr. C. E. Bortner.

percentage of chlorine in the leaf for the treatment of 800 pounds per acre but the rate of increase was less. The percentage of chlorine in tobacco receiving the same fertilizer treatment was greater in some years than in others, probably due to differences in weather conditions.

The small increases in percentage of chlorine in the leaf with increasing sulfate of potash treatments were no doubt due to the small amount of chlorine contained in the commercial sulfate. The percentages of chlorine present in the sulfate used during the last four years of the experiment were as follows: 1926, 0.35; 1927, 0.71; 1928, 0.71; 1929, 3.33. As indicated in Table 1, the percentages of chlorine in the leaf from the plats receiving no potash additions are averages of check plats used during the respective years. Only small differences existed in the chlorine content of the leaf from the different check plats in any particular year of the experiment. In 1926, six check plats (a larger number than usual) were used. The percentages of chlorine contained in the leaf from these different check plats are as follows: 0.16, 0.13, 0.16, 0.15, 0.10, 0.12.

Certain fertilizer treatments used in the experiments are not included in Table 1. During the first three years sodium chloride treatments were used. In 1925 and 1926 sodium chloride was applied to contain an amount of chlorine equivalent to that contained in 100 pounds per acre of muriate of potash. In 1924 equal weights of sodium chloride and muriate of potash were applied; viz, 100 pounds per acre. The average percentage

TABLE 1. Chlorine content, as percentage of the moisture-free tobacco leaf, exclusive of the midrib and larger veins.

Potash Treatment, Lbs. Per Acre	1924	1925	1926	1927	1928	1929	Ave.
1 None (average of check plots).....	.05	.05	.14	.05	.11	.08	.08
2 Muriate of potash 50.....			.44	.54	.49	.46	.48
3 Muriate of potash 100.....	.18	.94	.77	1.16	.75	1.41	.87
4 Muriate of potash 200.....			1.46	3.30	2.45	2.82	2.51
5 Muriate of potash 400.....				5.56	4.39	3.53	4.49
6 Muriate of potash 800.....				6.51	5.94		6.23
9 Sulfate of potash 50.....			.16	.04	.06	.10	.09
10 Sulfate of potash 100.....	.06	.05	.13	.04	.08	.07	.07
11 Sulfate of potash 200.....			.14	.05	.14	.36	.17
12 Sulfate of potash 400.....				.08	.83		
13 Sulfate of potash 800.....				.22	1.60		

of chlorine in the tobacco for the three years when treated with the sodium chloride was 0.81. The percentage in the tobacco treated with 100 pounds per acre of muriate of potash was 0.63. Chlorine in sodium chloride was as effective in increasing chlorine content in the leaf as chlorine in muriate of potash. In 1926 a broadcast application of 100 pounds per acre of muriate of potash increased the percentage of chlorine in the leaf as much as the corresponding row application.

Sulfur Content. Many of the tobacco samples were analyzed for sulfur. These analyses are shown in Table 2. Some increase in percentage of sulfur in the leaf is evident with increasing applications of sulfate of potash. The average percentage of sulfur in the tobacco from the check plats was 0.57; in that from the plats which received 800 pounds per acre of sulfate of potash it was 1.02. This increase is small as compared with the increase in chlorine due to an equal application of muriate of potash. The heavy muriate of potash treatments reduced slightly the percentages of sulfur in the leaf.

TABLE 2. Sulfur content, as percentage of the moisture-free tobacco leaf exclusive of the midrib and larger veins.

Treatment, Lbs. Per Acre		1926	1927	1928	1929	Average
1	None	.43	.53	.61	.72	.57
4	Muriate of potash 200	—	—	—	.81	—
5	Muriate of potash 400	—	.40	.52	—	.46
6	Muriate of potash 800	—	.41	.40	—	.41
9	Sulfate of potash 50	.39	.58	.61	.70	.57
10	Sulfate of potash 100	.43	.66	.62	.75	.62
11	Sulfate of potash 200	.46	.79	.71	.96	.73
12	Sulfate of potash 400	—	1.07	.73	—	.90
13	Sulfate of potash 800	—	1.19	.84	—	1.02

Quality. In each year of the experiment, after the leaf was stripped and ready for market, the tobacco from the different plats was carefully examined as to quality, including color, texture and case. For the most part no effects were observed from any of the sulfate of potash treatments during the experiment. In 1928 the tobacco that received the 800 pound per acre sulfate treatment was of slightly better quality than that from the check plats. In 1929 the soil of the plat area was

somewhat different from that in the other years and not so well adapted to tobacco. In this year the tobacco from all the sulfate plats was of better quality than that from the check plats. Potassium was not a limiting nutrient for crop growth in most of the years of the experiment so improvement in quality from its addition was not to be expected.

No effects on quality were observed from any of the muriate of potash treatments in 1924, 1925, and 1926. From Table 1 it is seen that the maximum muriate application in this period was 200 pounds per acre in 1926. In the three remaining years of the experiment the medium and heavy muriate of potash treatments did affect, very materially, the quality of the tobacco. Tobacco so affected was of a lighter color—a pale yellow color instead of the desired light brown, and tended to be in higher case than tobacco from the untreated and sulfate-treated plats. The change in color was particularly noticeable on the mid-ribs of the leaves. In 1927 these effects were very marked and quite objectionable in tobacco from the plats that received 400 and 800 pounds per acre of muriate of potash. The effects were less but still objectionable in the 200-pound-per-acre treatment. The 100-pound-per-acre treatment changed the appearance of the tobacco to an easily noticeable extent and even the 50-pound treatment to a slight extent. However, the sale value of the tobacco was lowered very little by the 100-pound treatment and probably not at all by the 50-pound treatment.

The effects of the muriate of potash treatments in 1928, in the main, were the same as in 1927. However, the 50- and 100-pound-per-acre treatments did not change the quality of the tobacco so much as in 1927 and there was an estimated appreciable increase in market value from both these treatments in this year. The 200-pound-per-acre treatment produced tobacco that tended to go into too high case and its color was objectionable. The 400- and 800-pound-per-acre treatments were quite objectionable, both because of high case and the light yellow color.

The effects of the 1929 treatments were very similar to those in 1928. An estimated appreciable increase in market value

resulted from the 50- and 100-pound-per-acre applications of muriate of potash. The 200- and 400-pound-per-acre treatments resulted in tobacco of pale yellow color and with a tendency to go into too high case. The 800-pound-per-acre treatment was omitted in this year.

Buyers on the floor of one of the loose-leaf sale warehouses were asked to compare the market value of tobacco grown in 1927 on a no-treatment plat and on plats that received, respectively, 200 and 800 pounds per acre of muriate of potash, but they would not do so definitely because of the marked difference in appearance and "feel" of the muriate-treated tobacco. Light-colored tobacco was in demand in this year but the muriate-treated samples were objected to because the color was light yellow instead of the usual light brown, and because of the high case.

A Commercial Test. As previously stated, in 1927 and 1928 approximately acre areas, respectively, of muriate- and sulfate-treated tobacco were grown and furnished to Liggett and Myers. In 1927, the potash materials were applied at the rate of 200 pounds per acre. This was done since in the previous year no injurious effect had resulted from the use of muriate of potash at this rate on the small plats. However, the muriate-treated tobacco from this acre area, just as in the case of the tobacco from the small plat in this year where the muriate treatment was at the same rate, was considerably changed in appearance and quality otherwise from the sulfate-treated tobacco. It had a light yellow color and a tendency to go into too high case. These effects were most noticeable in the flyings, trash and lugs; they were less noticeable in the bright leaf, and slight in the red leaf and tips. This also was true to a greater or less extent for the effects of the medium and heavy muriate treatments on the tobacco in general in the experimental work reported in this publication.

In 1928, the tobacco was fertilized with 100 pounds per acre of the two potash materials instead of 200 pounds as in the previous year. No differences in quality between the two lots of

tobacco were observed in this year. In addition to the fact that the potash treatments were smaller, it should be kept in mind that, as already stated, the 50- and 100-pound per acre treatments of muriate did not change the quality of the tobacco grown on the small plats as much in 1928 as in 1927.

The tobacco grown on these acre areas was put into the regular hogsheads in the Company's redrying plant in Lexington and shipped to their St. Louis plant, where, after going thru the usual factory treatment and aging process, the two differently fertilized lots were examined by Dr. H. L. Schulz, of their research department, for effects of the treatments on quality of the tobacco.

In regard to the 1927 tobacco, Dr. Schulz stated in correspondence that "the chloride-fertilized tobacco differed greatly from the tobacco fertilized with the sulfate. There was a marked difference in the body, color, odor, flavor, and burning qualities. In each respect the sulfate tobacco was the better. . . . On smoking the chloride tobacco, a black ash remains, while the sulfate tobacco leaves a gray ash." In regard to the 1928 tobacco he stated that there was very little difference in the appearance of the two lots of tobacco after going thru the usual factory treatment and aging processes.

Small amounts of lugs from the 1927 muriate, and sulfate-treated tobacco were sold on the Lexington loose-leaf market. The sulfate-treated lot brought 35.5 cents per pound; the muriate-treated lot brought 26.3 cents per pound.

Ground samples of the various grades of the two lots of 1927 tobacco, after going thru the curing process, were sent to the Experiment Station. The chlorine content in these samples was determined. The results are shown in Table 3. It will be noted that the muriate treatment greatly increased the percentage of chlorine in all the grades. As previously stated, the effect of this treatment in changing appearance of the tobacco was much the greatest in the lighter grades that come from the lower part of the stalk. It was thought that this might be due mainly to a larger uptake of chlorine by the older, lower leaves, but the analyses shown in Table 3 scarcely bear this out.

Samples also were obtained from the flyings and the red leaf from the tobacco grown on the small plat in 1928 which was fertilized with 400 pounds per acre of muriate of potash. These were analyzed for chlorine. The percentage found in the flyings was 4.21 and in the red leaf, 4.36. The effect of muriate treatment in lowering quality in the lower leaves to a greater extent than in the upper leaves probably is brought about, at least mainly, in other ways than thru a greater increase in the percentage of chlorine present.

TABLE 3. Chlorine content of the various grades of the two lots of tobacco grown in 1927 and sent to Liggett & Myers.

Grade	Percent Chlorine in Dry Tobacco Fertilized With 200 Lbs. Per Acre of	
	Potassium Chloride	Potassium Sulfate
Flyings* _____	4.74	.07
Trash _____	5.22	.08
Lugs _____	5.06	.13
Bright leaf _____	4.18	.10
Red leaf _____	3.41	.08

* The kind called flyings is from the lowest part of the stalks. It is light, trashy tobacco. Red leaf is from the top part of the stalks. It is heavy, red colored tobacco. The other grades are in order in between and are intermediate in characteristics.

Burning Quality. Careful burning tests were made at the Station on the samples of tobacco grown on the small plats in 1927 and 1928, including rate of burn, length of burn (i. e., length of time remaining lighted), and color of ash. It will be recalled that the samples were prepared by breaking up the tobacco with the hands when in air-day condition till it passed thru an 8-mesh sieve, removing all the midrib and pieces of the large veins in the process. The portions of these samples used for the smoking tests were further prepared by placing on a 20-mesh sieve and discarding the small part that went thru.

After trial of various methods, it was decided to use the following procedure in this work. The tobacco was made into cigarettes which were smoked in vertical position in a mechanical smoker by which a continuous, even suction could be applied to the cigarettes. Suction from a water-aspirator pump was applied to a two-liter bottle and thence to the cigarette. The

partial vacuum in the bottle was kept practically constant by connecting it to a second bottle containing a heavy liquid (sulfuric acid was used) with a glass tube extending 11 cm. below the surface of the liquid, thru which air was able to enter the apparatus. To prevent changes in rate of movement of air thru the cigarettes due to mechanical differences in their making, a glass tube with an opening at one end of 0.3 mm. diameter was introduced between the cigarette and the two-liter suction bottle. Tests showed that the opening in this tube was sufficiently small so that it offered a greater resistance to air movement than the cigarettes and thus determined the rate of air movement. A small flask was introduced between this tube and the cigarette. This flask contained water thru which the stream of air with the combustion products from the cigarette bubbled, removing material which otherwise might clog the small opening in the tube.

In making the cigarettes, white cigarette papers were rolled around a glass tube 8 mm. in diameter and 71 mm. long. To prevent the paper from becoming moist from the combustion products during burning, causing uneven burn, a thin coating of vaseline containing a small amount of sodium chlorate was applied to one side of the paper and the rolling done so that this came next to the tobacco. Flour paste containing sodium chlorate was used to hold the edges of the paper together. This paper form was slipped into a glass tube of slightly larger diameter and filled with tobacco, compacting the tobacco in all cigarettes, as uniformly as possible by hand, using a glass rod with a flattened end slightly smaller than the cigarette.

In the rate-of-burn tests, determination was made of the length of time required to burn a 50 mm. length of cigarette. As a check on accuracy, this was done by timing the burning of 12.5 mm. lengths, but in the results reported these are combined into the time required to burn the 50 mm. lengths. Considerable variation frequently existed in the results from different cigarettes and it was necessary to discard the entire results from an occasional test but in the main the results were consistent. Those reported are averages, usually of tests on 4 to 6 cigarettes.

Detailed results from the tests on one of the samples are shown in Table 4.

TABLE 4. Detailed results of rate-of-burn tests with sample from Plat 2. 1927.

Portion of Cigarette Burned	Seconds Required for:					
	1st cigarette	2nd	3rd	4th	5th	6th
0—12½ mm.	26	22	21	14	20	29
12½—25 mm.	19	20	20	27	25	25
25—37½ mm.	22	18	20	15	20	18
37½—50 mm.	19	20	17	23	18	17
Combined 0—50 mm.	86	80	78	79	83	89

The length-of-burn tests were made by cutting off the flow of air thru the cigarette and noting how long it stayed lighted, as evidenced by the giving off of smoke, checked by noting whether the cigarette was or was not still lighted when air flow was renewed. It was attempted as nearly as possible to have an equal number of times when the cigarette was still lighted and when it was not lighted for the time periods used. Usually 6 or 7 tests were made with each cigarette and the results reported are averages, generally from two cigarettes. Detailed results from the tests on one of the samples are shown in Table 5.

TABLE 5. Detailed results of length-of-burn tests with sample from plat 2. 1927.

Number of Test	Seconds cigarette remained lighted after air current was cut off		
	1st (cigarette)	2nd	3rd
1	60	52	45
2	60	52	60
3	45	40	50
4	60	55	50
5	55	45	45
6	45	45	40
7		42	
Average	54	47	48
Average of the three cigarettes	50		

Ash from the rate-of-burn tests was compared for differences in color and mechanical condition.

The combined average results from these tests are shown in Table 6. The effect of chlorine in the fertilizer treatments in

TABLE 6. Combined averaged results from the burning tests on the samples of the 1927 and 1928 tobacco.

Treatment acre basis Pounds	Length of time required for 50 mms. of cigarette to burn		Length of time cigarette remained lighted after air current was cut off		Nature of ash
	1927 tobacco seconds	1928 tobacco seconds	1927 tobacco seconds	1928 tobacco seconds	
None	82.5	109	50	52	} Light gray to gray, almost free from carbon particles.
None	94	97	37	60	
50 KCl	92	87	45	54	} Same as no treatment.
100 KCl	106	103	41	49	
200 KCl	116	120	25	36	} 2/3 of ash same as no treat- ment ash, 1/4 dark carbon ma- terial, remainder intermediate.
400 KCl	124	130	15	26	
800 KCl	122	170	10	23	} 1/3 to 1/2 of ash same as no treatment ash, 1/3 dark carbon material, remainder intermed- iate. Slightly darker in 1928 than in 1927 tobacco.
50 K ₂ SO ₄	95	102	41	37	
100 K ₂ SO ₄	88	95	40	48	} 1927 ash practically same as ash from 400-pound muriate treatment in this year. 1928 ash mainly dark carbon ma- terial.
200 K ₂ SO ₄	102	90	40	40	
400 K ₂ SO ₄	82	84	41	40	} Same as no treatment.
800 K ₂ SO ₄	106	122	42	41	
					} 1927 ash slightly darker than no treatment ash. 1928 ash almost same as ash from 800- pound sulfate treatment in this year.
					} 1927, ash darker than ash from 400-lb. sulfate treatment in this yr., 1/5 of ash a dark color but not black as carbon part of ash from heavy muriate treatments. 1928, ash darker than preceding, 1/3 of ash a dark color but not black as carbon part of ash from heavy muriate treatments.

decreasing rate of burn and particularly in reducing fire-holding property and in giving a dark ash is evident when the treatments of muriate of potash were 200 pounds per acre and above. It is to be emphasized that these detrimental effects were not evident with the 50- and 100-pound-per-acre applications. It will be noted that the 400- and 800-pound-per-acre treatments of potassium sulfate also gave less desirable burning properties and a darker ash than the check and other potassium sulfate treatments.

Burning tests were made on cigarettes of four of the leading commercial brands. Cigarettes of all these brands burned continuously until burned up, in vertical position, in the absence of any air movement. The average time required to burn 50 mm. was 23 minutes. Tobacco of one of the commercial brands was removed from the factory papers and made into the hand type of cigarette used in the laboratory experimental work. The average length of time such cigarettes would stay lighted after the air current was cut off was 88 seconds. This compares with 96 seconds as an average of the no treatment tobacco for the years 1927, 1928. The ash from the commercial cigarettes was not quite so light in color as that from the sample from the untreated plots.

SUMMARY

White Burley tobacco was grown for 6 years, 1924-1929, on the Experiment Station farm at Lexington on small plats fertilized with varying amounts of muriate and sulfate of potash. The effects of the treatments were determined on the appearance, "feel", chlorine and sulfur content, and in two years on the smoking qualities of the tobacco. In 1927 and 1928 tobacco was grown on larger areas and sold to Liggett and Myers so that the effects of the treatments on quality could be determined after the tobacco had gone thru the regular redrying, aging and factory processes of the Company. Some variation existed in the effects of the treatments in different years. In all years the effect of adding fertilizers containing chlorine was to increase the chlorine content of the tobacco. In most years there was no

apparent injurious effect in any way on the tobacco from applications of 50 or 100 pounds of muriate of potash per acre. However, in one year a slightly injurious effect was observed from a 100-pound-per-acre application. In another year no injurious effect was observed from a 200-pound-per-acre application; usually this amount injured the tobacco to a considerable extent. Applications of 400 and 800 pounds per acre injured the appearance and other qualities of the tobacco to a large extent. The sulfate treatments affected the percentage of sulfur in the tobacco to a small extent and the appearance and "feel" of the tobacco very slightly or not at all.

Burning tests on the 1927 and 1928 tobacco grown on the small plats showed that no detrimental effect resulted from the 50- and 100-pound-per-acre applications of muriate of potash. The 200-, 400- and 800-pound-per-acre applications of this material injured the burning qualities, the 200-pound rate to an appreciable extent, and the 400- and 800-pound rates to a marked extent. Some injury in burning qualities also resulted from applications of 400 and 800 pounds per acre of sulfate of potash.

On the basis of these experiments and on soils similar to the ones used in the experimental work, no injurious effect of any kind on White Burley tobacco would be expected from the application of 25 pounds per acre of chlorine in fertilizers and in general no injurious effect of consequence would be expected from applications up to twice this amount.